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REMOTELY CONTROLLED CHAIN OF MULTI-SENSING DEVICES

HP INC

Remotely controlled chain of multi-sensing devices

Abstract

An additive 3D printer with automatic material extraction and cleaning is a complex mechanism which combine multiple elements to transport air and powder. We have developed this invention which allows to remotely sense physical properties of the air and powder (such as air-pressure, differential pressure, temperature, humidity, filter status...) thanks to a combination of modular sensor devices connected through an electronic chain which constantly sends information to the host controller.

Description

There is not an existing solution that is able to deliver this functionality. Other products may combine other technologies to implement a similar operation but with significantly increased cost, size and function limitation.
For example Ethercat (https://en.wikipedia.org/wiki/EtherCAT) from the company Beckoff provides a similar solution that can be used to control an industrial sensor environment. However, this solution is very complex, requires larger size devices as well as much more powerful processors to manage the protocol stack.

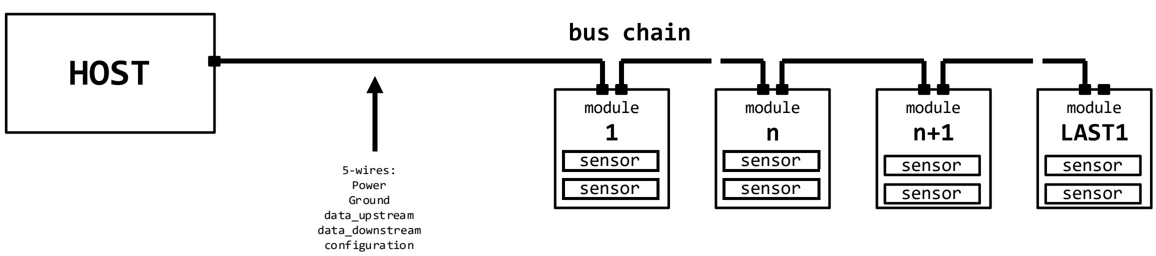

Figure 1

The invention disclosed herein contains a plurality of modules, each of them containing one or more sensors. These modules can be connected in parallel mode, daisy-chain mode or a combination of the previous (see, e.g., figures 1 and 2). The connection consists on 5 wires (power, ground, data_upstream, data_downstream and configuration). Ssome applications enable a very high speed by splitting each data wire into two wires and use differential signaling.

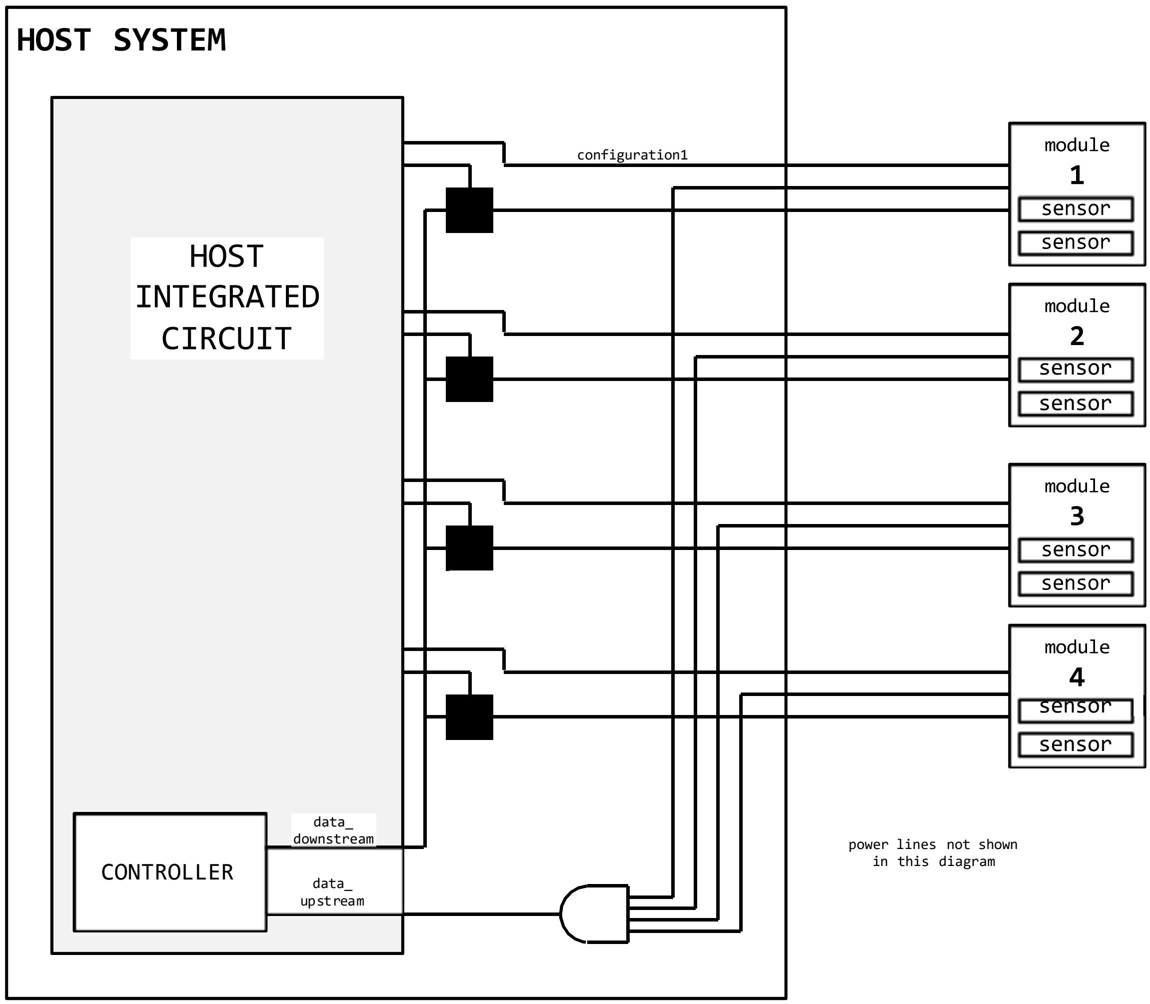

Figure 2

Modules can be identical or different with each other. Each module contains a micro-controller, which manages the communication protocol and a group of sensors, electrically connected to the micro-controller (figure 3). The micro-controller directly reads the analog output of the sensors (through an analog-to-digital converter) and encodes the data into a digital format to be sent to the host through the electrical lines (data_upstream channel). In other cases, the sensor may communicate to the processor through a digital interface protocol (such as I2C or SPI). In these situations, the micro-controller decodes this protocol, gets the data and encodes again the information into the data_upstream channel.

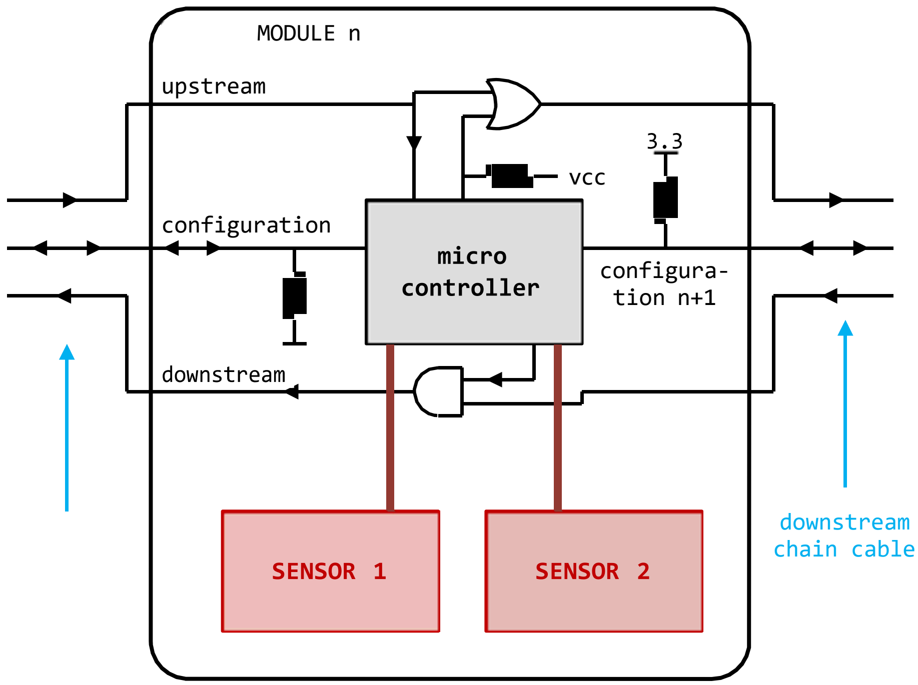

Figure 3

A time-based slot system is used to determine which of the module respond at any specific time such there are not collisions in the data_upstream channel.
All the information returns to the host. However, the intermediate modules can read the data and use its information if necessary.
The host also manages a data_downstream channel which reaches all the modules. Through this channel the host can perform several actions, such as to configure each of the modules and assign each of them to a specific response time slot.
The additional configuration wire is used for asynchronous, real-time side band functions. One of the functions is to reset the micro-controller in case there is a software error which halts one of the micro-controller. Another function is to determine if a particular module is connected to the network.
Each module controls several sensors. As explained above, these sensors may have analog or digital interface to the micro-controller. Common types of sensors are pressure sensors, humidity sensors, and pressure sensors. In some cases the micro-controller can use the values of more than one sensor to generate specific information. An example would be to generate absolute humidity values based on the temperature and relative humidity from the sensors. In other cases, the micro-controller can interface to mechanical sensors such as filter presence or filter full sensors.
Furthermore, the micro-controller can implement functions like noisy filtering or data averaging.
Figure 4 shows an implementation of this invention. Some implementation examples in 3D printers use more than 25 instantiations of this module.

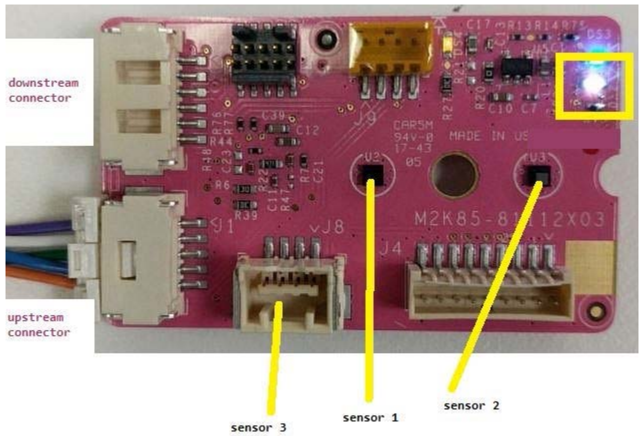

Figure 4

This invention allows for a very reliable real time data gathering from a high quantity of sensors distributed in multiple places of a 3D printer. This solution enable a small size, reliable cabling and a low cost product. Other solutions and any existing similar solutions in the industry required much larger size, offered very poor electromagnetic noise immunity, and could not provide the accuracy of sensor measurement as opposed to the solution disclosed herein.

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